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(54) Treatment of aqueous waste material

(57) A sludge digestion tank 2 has three chambers 8, 10 and 12. There are common walls 14 and 16 between the chambers 8 and 10 and the chambers 10 and 12 respectively. Batches of digested sludge are withdrawn at chosen intervals from the chamber 12 through the outlet 20. The chamber 12 is replenished with sludge from chamber 10 and the chamber 10 likewise with sludge from chamber 8. Untreated sludge is passed through inlet 18 into the chamber 8. The sludge in at least one of the chambers is oxygenated, and the chambers 10 and 12 are operated at higher temperatures than the chamber 8 and in the thermophilic temperature range. It is possible using the apparatus to obtain satisfactory residence times for the sludge while obtaining the advantages of thermophilic digestion.

FIG.1.

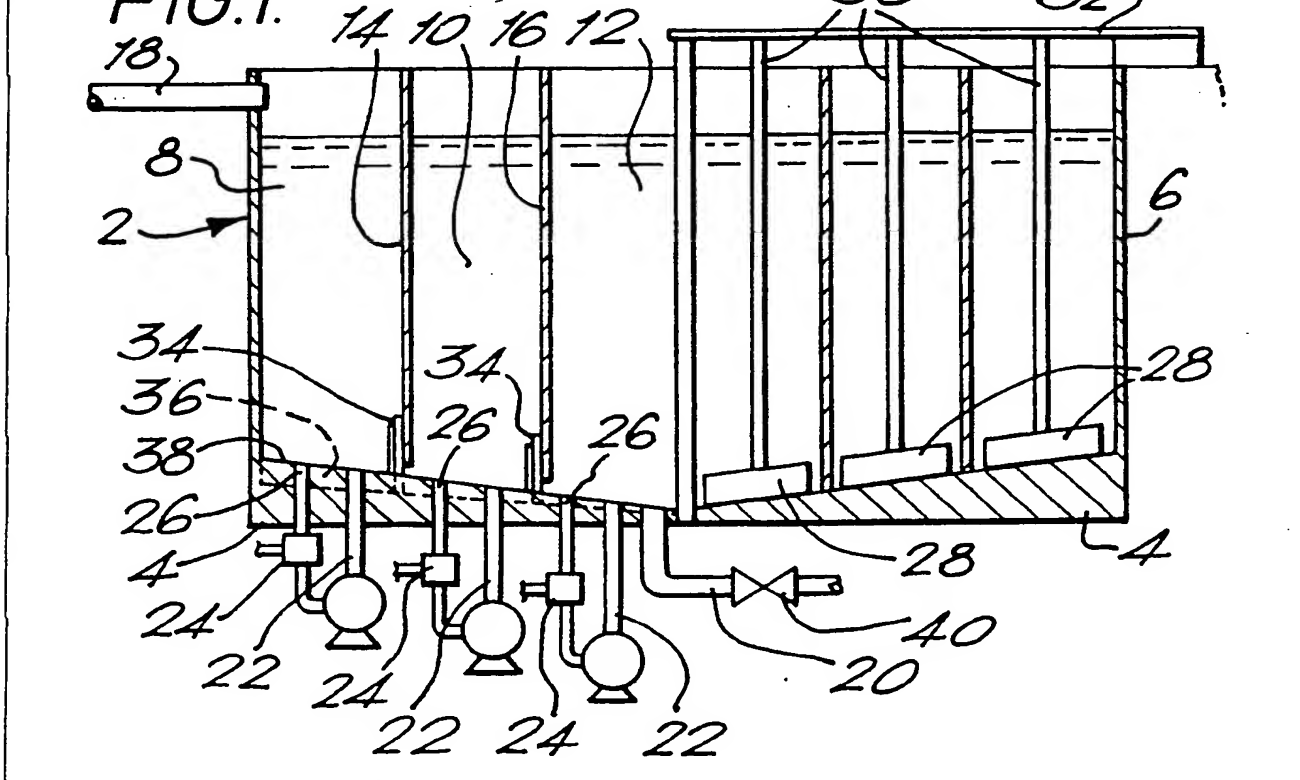

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FIG.1.

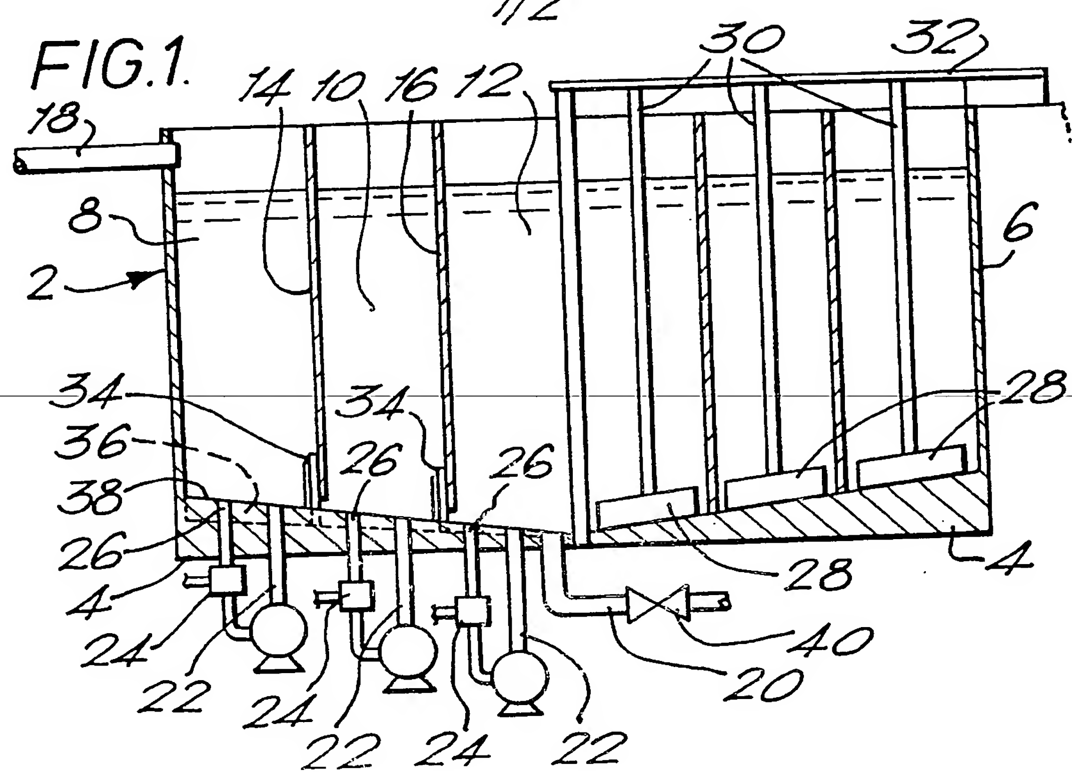
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FIG.2.

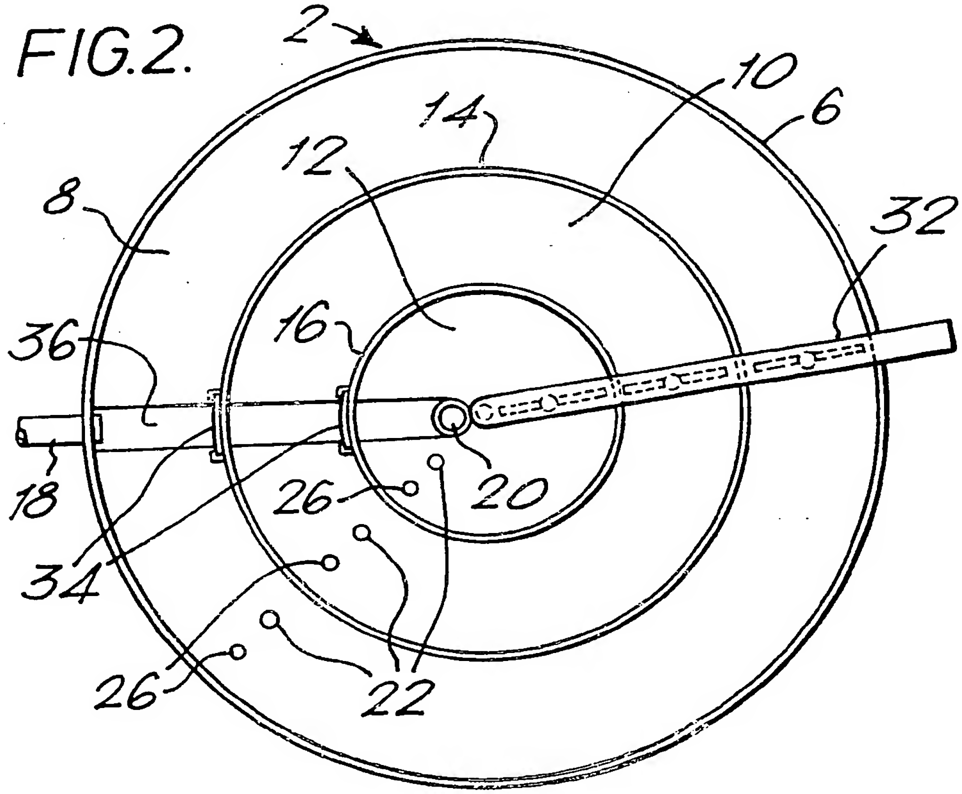
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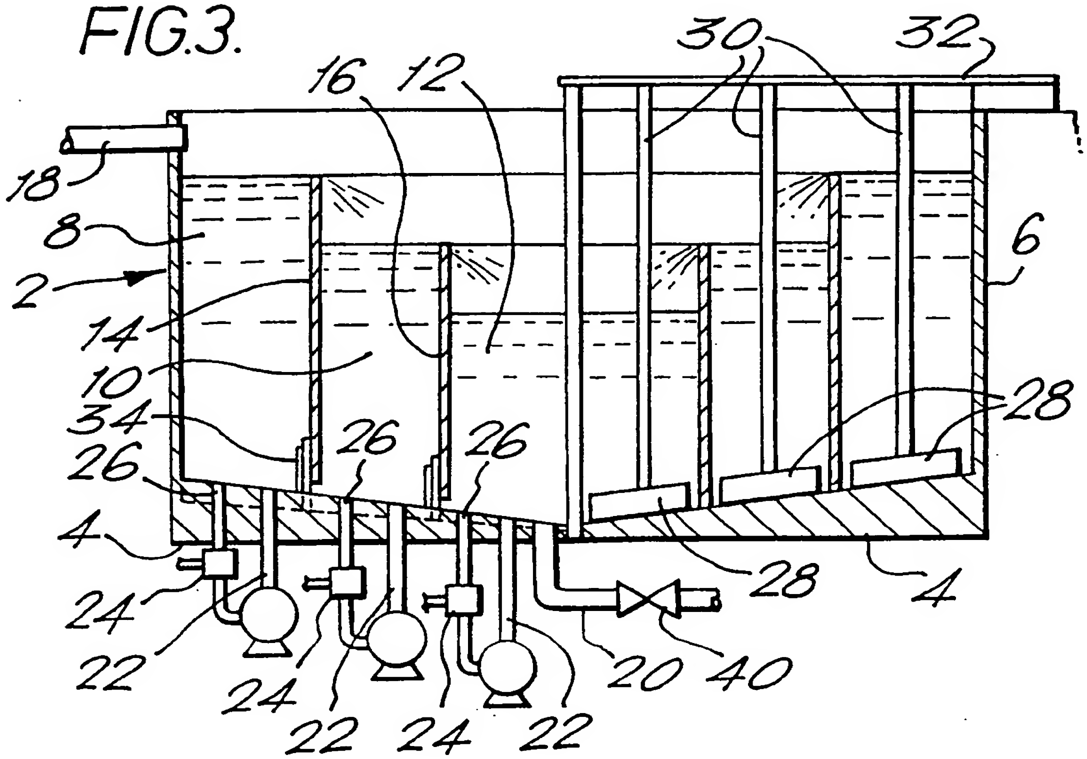
FIG.3.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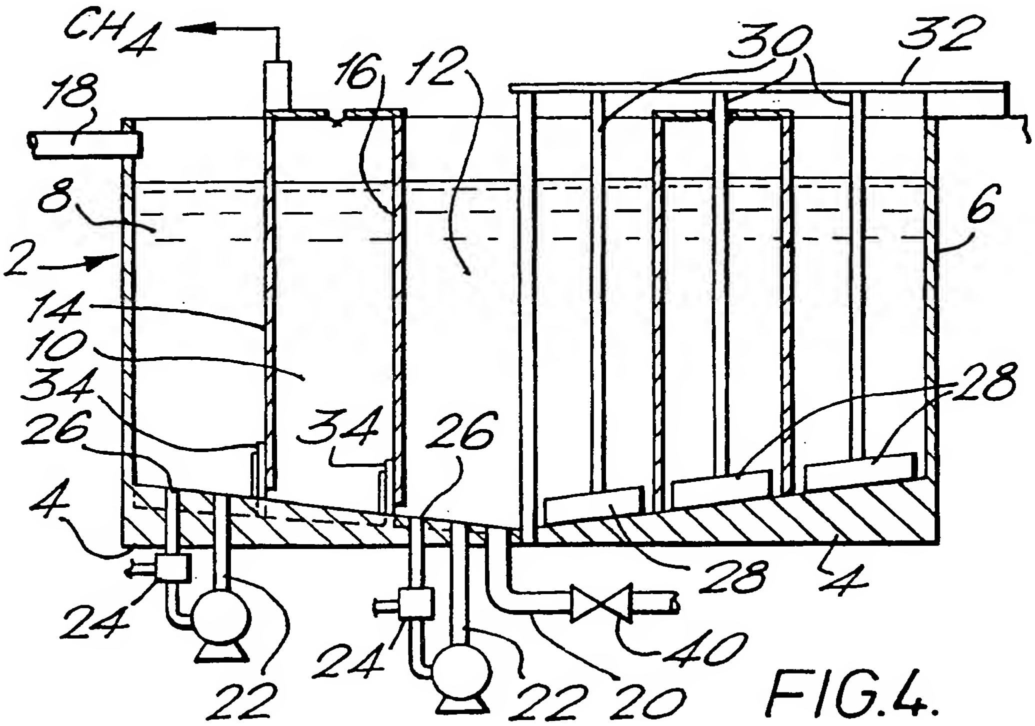
CH4
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FIG.4.

SPECIFICATION

Treatment of aqueous waste material

This invention relates to the treatment of aqueous waste material. In particular, it relates to apparatus and methods for the digestion of sewage sludge.

In the treatment of sewage in a conventional municipal or other sewage works, there is generally a primary treatment stage in which larger solid material is allowed to settle out from the sewage and a secondary treatment stage in which waste materials in the sewage are oxidised by a bacterial biomass known as activated sludge. During this stage of the process, the bacteria reproduce and thus the amount of sludge increases. Consequently, the material settling out in the primary treatment stage and excess sludge produced in the secondary treatment stage need to be withdrawn and subjected to further treatment to render them fit for disposal either at sea or by being spread upon the land.

Conventionally, such further treatment involves the anaerobic digestion of the sludge by bacteria, a process which results in a reduction in the volume of the sludge. The bacteria which take part in the process as mesophilic bacteria, that is bacteria active in the temperature range 10 to 35°C.

A number of disadvantages are associated with conventional anaerobic sludge digestion processes. First, such processes are relatively slow and take some 30 days for the digestion to be completed. Secondly, it is found that the process tends not to be particularly effective in combating pathogens such as viruses and the eggs of tapeworms or hookworms. Thirdly, as the process is endothermic and as it is preferred to work in the upper part of the mesophilic temperature range (10 to 35°C) the vessel in which the digestion takes place needs to be heated by means of an external source of heat. On the other hand, one advantage of conventional anaerobic digestion processes is that they generate a combustible gas, methane, and thus energy can be recovered from this gas.

In order to provide a process which offers advantages over conventional anaerobic digestion of sludge it has been proposed to digest the sludge aerobically in the thermophilic temperature range by means of thermophilic bacteria. These are bacteria that are active at temperatures above 35°C. Generally, the optimum temperature for thermophilic bacteria is in the range 52 to 60°C. Such aerobic digestion of the sludge is a much more rapid process than conventional anaerobic mesophilic digestion and, in view of the relatively high operating temperature, it is more effective against pathogens. On the other hand, no combustible gas as methane is produced.

In practice, aerobic thermophilic digestion of sludge has been operated as a batch process. It has been found that the process requires only three to four days to remove about 50% of the volatile solids, that more than 99.9% of pethogens are killed and the digested sludge does not have an offensive smell, even after a month, giving ample time for it to be spread onto the land. Typically, plant that has been used for aerobic thermophilic digestion comprises a single tank from which a quarter of its contents is emptied, typically once a day, and replaced with incoming sludge for digestion. A disadvantage of this procedure is that part of the sludge is exposed to thermophilic oxygenation for only 24 hours thereby resulting in some of the pethogens passing through the process without being killed.

In order to overcome this disadvantage, we have proposed in our UK patent specifications 1 581 432 and 2 051 769 to pass the sludge through an elongate digestion zone, typically spiral, and arrange for relatively warm digested sludge to be heat exchanged with incoming relatively cold undigested sludge so as to raise the incoming sludge to temperatures at which thermophilic bacteria are active. In practice, we believe that the plant necessary for performing these processes may have a relatively high cost.

It is therefore an aim of the present invention to provide an alternative method and apparatus for the thermophilic digestion of sludge.

According to the present invention there is provided apparatus for the thermophilic digestion of bacterial sludge comprising at least two treatment chambers for holding sewage sludge having a common wall across which heat can be exchanged, means for allowing or causing sludge to flow from one chamber to the other, means for withdrawing sludge from said other chamber, and means for oxygenating the sludge in at least one of the chambers.

The invention also provides a method for the thermophilic digestion of bacterial sludge comprising the steps of passing the sludge into a first treatment chamber holding sludge being digested, passing sludge from the first treatment chamber to a second treatment chamber also holding sludge being digested, and withdrawing digested sludge from the second chamber, the two treatment chambers having a common wall across which heat is exchanged, and oxygenating the sludge in at least one of the chambers.

By transferring sludge being digested from the first treatment chamber to the second, it is possible to achieve satisfactory residence times for all the sludge in the apparatus while still being able to receive new sludge for treatment at regular intervals, typically of a day.

Preferably, the chambers or at least two of

the chambers are operated at different temperatures from one another.

Preferably, the or each common wall is endless. In a preferred embodiment of the apparatus there are at least three chambers and two endless common walls, one such wall defining a boundary between a first and a second chamber, and the other such wall defining a boundary between the second and third chamber. Preferably, the walls of the chambers are generally tubular (ie generally circular in cross-section), the chambers being arranged concentrically. Typically, batches of sludge may be passed from one chamber to the next at intervals in the range 18 to 36 hours. Preferably, the first chamber encountered by incoming sludge for treatment contains sludge at a temperature in the range 35 to 40°C. Since the incoming sludge for treatment will typically be at ambient temperature, the thermal shock to which it is subjected when introduced into sludge at a temperature of 35 to 40°C will be relatively small and is unlikely to have an adverse affect on the thermophilic bacteria. In this example of the method according to the invention, the sludge in the first chamber encountered by the incoming sludge is oxygenated. Preferably, the sludge in the other chamber or chambers is generally maintained at a temperature in the range 50 to 60°C. It is not essential to digest the sludge in the other chamber or chambers by an aerobic (or oxic) method. Instead, they can be operated anaerobically to enable a combustible gas to be produced. Typically, the first and last chambers encountered by the sludge may be operated aerobically with oxygen being dissolved in the sludge and the intermediate chamber or at least one of the intermediate chambers operated anaerobically (but in the thermophilic temperature range). An advantage of such an arrangement is that the heat generated by the exothermic aerobic (or oxic) digestion of the sludge may be used to maintain the anaerobic chamber or chambers at a suitable temperature without recourse to any external source of heat.

The thickness of the or each common wall may be chosen according to the desired average residence time of the sludge in the chamber or chambers it bounds. Each chamber may be open at its top or may have a roof and the non-common walls may be thermally insulated.

Flow of sludge from one chamber to an adjacent chamber may be over a weir intermediate the two chambers or through a penstock in a common wall therebetween.

Typically, the chambers are provided with means for removing inorganic material settling at the bottom thereof.

A conventional sludge digestion tank may be readily converted into an apparatus according to the present invention. The common walls may be located inside such a conventional digestion tank at desired locations and may be formed of material such as vitreous steel (eg steel coated with enamel). Typically, each such common wall may be formed from panels of vitreous steel bolted or otherwise fastened together.

The method and apparatus according to the present invention will now be described by way of example, with reference to the accompanying drawing, in which:

Figure 1 is schematic side elevation of a sludge digestion tank for use in the present invention;

Figure 2 is plan view of the tank shown in Fig. 1, and;

Figures 3 and 4 are schematic side elevations illustrating alternative tanks for use in the present invention.

Referring to Figs. 1 and 2 of the drawings, the sewage sludge digestion tank 2 has a base 4 and a right cylindrical side wall 6 and is open at its top. Within the tank 2 are three treatment chambers 8, 10 and 12. The outermost chamber 8 is generally annular and is defined by the wall 6 and a right cylindrical wall 14 which is common to the chambers 8 and 10. Chamber 10 is also annular, being defined by the wall 14 and a similar wall 16 which is common to the chamber 10 and the chamber 12. Chamber 12 is generally cylindrical being defined by the wall 16. The walls 14 and 16 cooperate with the floor 38 of the tank 2 such that in normal operation of the tank no liquid can flow from one chamber to another between one of the walls and the floor 38.

The tank 2 has an inlet pipe 18 associated with it and arranged so as to feed sludge, typically from a municipal sewage treatment plant, onto the surface of the liquid in the chamber 8. The tank has an outlet 20 communicating with the bottom of the chamber 12 so that sludge may be withdrawn from the tank. Thus, sludge may be fed into the tank at regular intervals and, at the same time, an equal quantity may be withdrawn from the tank 20.

Each of the chambers 8, 10 and 12 is fitted with a sludge withdrawal pipe 22 which leads from its interior to an oxygenator 24 which in turn communicates with nozzles for injecting oxygenated sludge to the respective chamber. The construction and operation of the oxygenators 24 and their associated equipment are as described in UK patent specification No. 1 455 567.

Each of the chambers 8, 10 and 12 has a scraper 28. Each scraper 28 is mounted on a shaft 30. The shafts 30 depend from a rotary arm or bridge 32 which is associated with a motor or other means for propelling it around the tank such that the scrapers 28 sweep the floor 38 of the chambers.

Each of the walls 14 and 16 has a penstock or sliding gate 34 cooperating with a single

radial channel 36 in the floor 38 of the tank 2 to prevent passage of liquid from one chamber to an adjacent chamber when the penstocks or gates are in their closed positions. However, the gates may be raised so as to allow passage of sludge to take place from the chamber 8 to the chamber 10 and from the chamber 10 to the chamber 12.

As well as receiving some of the penstocks for sliding gates 34, the channel 36 acts as a receptacle for inorganic solids swept along the floor 38 by the scrapers 28. When the penstocks are open, the inorganic solids will be washed from one chamber to the next with rest of the sludge and will eventually be discharged with the sludge through the outlet 20. The channels 36 and the floor 38 slope towards the outlet 20 so as to assist such flow of solids.

The outlet 38 has a valve 40 disposed therein. The valve 40 may be opened periodically to enable digested sludge to be discharged from the tank 2.

The apparatus shown in Figs. 1 and 2 may be operated as follows. With the chamber 8 containing a volume of sewage sludge at a temperature of, say, 35°C, the chamber 10 containing sewage sludge at a temperature of, say, 50°C (ie in the thermophilic range), and the chamber 12 containing sludge at, say, 60°C (ie in the thermophilic range), the valve 4 is opened and a volume of digested sludge run out of the chamber 12 through the outlet 20. The chamber 12 is replenished with sludge by opening the penstock 34 associated with the wall 14 thereby allowing sludge to flow from the chamber 10 into the chamber 12. Similary, in order to replenish chamber 10, the penstock associated with the wall 14 is opened to allow sludge to flow from the chamber 8 into the chamber 10. The chamber 8 is replenished by causing a volume of untreated sludge to flow into the tank 2 through the inlet 18. This untreated sludge will typically be at ambient temperature (say around 20°C). Accordingly, there will be a reduction in the temperature of the sludge in each chamber as a result of its being mixed with incoming sludge at a lower temperature. A portion of the sludge in each chamber is thus withdrawn through the pipe 22, oxygenated in the oxygenator 24 and returned to the respective chamber through the nozzles 26. Accordingly, the bacterial digestion process takes place giving out heat which raises the temperature in each chamber. When the temperature of the sludge in each chamber has been restored to its value immediately before discharge of sludge therefrom, oxygenation may be discontinued and then performed only intermittently so as to maintain the temperature at each level. After a chosen period of time, the valve 20 and the penstocks 34 may be reopened and further withdrawal of sludge from the chamber 12, and transfer of sludge from chamber 8 to chamber 10 and from chamber 10 to chamber 12 may take place along with further incoming sludge for digestion being introduced into the chamber 8 from the inlet 18.

Typically, sludge may be withdrawn from the chamber 12 at intervals of, say, 24 hours for the average residence time of sludge in the tank 2 arranged to be from 3 to 4 days. By this means, premature discharge of sludge before substantially all the pathogens in it have been killed or sterilised may be avoided. In addition, by maintaining the temperature of the sludge in the outer chamber 8 at, say, 35°C, the risk of causing damage to thermophilic bacteria by thermal shock is kept to a minimum.

In view of the above-ambient temperatures maintained in the chambers 8, 10 and 12, the treatment therein will be a thermophilic digestion and not a mesophilic one. In other words, it is the thermophilic bacteria rather than mesophilic bacteria that are active in the digestion process.

In each of the chambers 8, 10 and 12 there is no directional flow of liquid. Newly introduced sludge will become mixed with sludge previously resident in each chamber. If desired, the mixing may be facilitated by operating stirrers (not shown) in each chamber.

From time to time, the scrapers 28 may be operated so as to move any accumulated solids into the channel 36. When the penstock are opened, the resultant scouring action of the flow of liquid from one chamber to the next will cause the solids or sediment in the channel to flow radially inwards with the sludge. All such solids will be discharged from the tank to the rest of the sludge through the outlet 20.

The apparatus shown in Fig. 3, and its operation, is substantially the same as that shown in Figs. 1 and 2, and like parts to those shown in Figs. 1 and 2 are identified in Figs. 3 by the same reference numerals as used in Figs. 1 and 2. The only difference between the apparatus shown in Fig. 1 and 2 and that shown in Fig. 3 is that in the latter the common walls 14 and 16 are formed as weirs over which sludge can flow from time to time from chamber 8 to chamber 10, and from chamber 10 to chamber 12 respectively. Accordingly, there is no need to form the common walls 12 and 14 with penstocks 34. In operation of the apparatus shown in Fig. 3 most of the inorganic solids are deposited at the bottom of the chamber 8. Thus, this chamber may have associated therewith a sump (not shown) into which the scraper 28 associated with such chamber 8 can propel them, and from which they can be transferred to the chamber 10 and may have a similar sump associated with it to enable solids to be transferred therefrom to the chamber 12.

The apparatus shown in Fig. 4 is substantially the same as that shown in Figs. 1 and 2 and accordingly, parts shown in Fig. 4 that have counterparts in Figs. 1 and 2 are identified by the same reference numerals as in Figs. 1 and 2. The main difference between the tank shown in Figs. 1 and 2 and that shown in Fig. 4 is that the latter has no oxygenation apparatus associated with its chamber 10, which chamber is fitted with a closure at its top to enable gas to be collected in an ullage space above the level of the sludge therein. Chamber 10 is operated anaerobically and thus the thermophilic bacteria break down organic materials in the sludge to form methane. The methane is collected in the ullage space and may periodically be withdrawn there-from. Typically, all the necessary heat required for the endothermic anaerobic digestion taking place in the chamber 10 is supplied across the common walls 12 and 14, such heat being generated as a result of the aerobic (or oxic) digestion reactions that take place in the chambers 8 and 12. If desired, the temperatures at which the sludge in respective chamber is maintained may be the same as that described with reference to Figs. 1 and 2.

CLAIMS

1. Apparatus for the thermophilic digestion of bacterial sludge comprising at least two treatment chambers for holding sewage sludge having a common wall across which heat can be exchanged, means for allowing or causing sludge to flow from one chamber to the other, means for withdrawing sludge from said other chamber, and means for oxygenating the sludge in at least one of the chambers.

2. Apparatus as claimed in claim 1, in which the or each common wall is endless.

3. Apparatus as claimed in claim 1 or claim 2, in which there are at least three chambers and two endless common walls, one such wall defining a boundary between a first and a second chamber, and the other such wall defining a boundary between the second and third chamber.

4. Apparatus as claimed in any one of the preceding claims, in which the walls of the chambers are generally tubular, the chambers being arranged concentrically.

5. Apparatus as claimed in any one of the claims 1 to 4, in which there is at least one weir over which sludge is able to flow from one chamber to another or the other chamber.

6. Apparatus as claimed in any one of claims 1 to 4, in which there is a penstock in the or each common wall to permit passage of sludge therethrough.

7. Apparatus for the thermophilic digestion of bacterial sludge, substantially as herein described with reference to, and as shown in Figs. 1 and 2, Fig. 3 or Fig. 4 of the accompanying drawings.

8. A method for the thermophilic digestion of bacterial sludge comprising the steps of passing the sludge into a first treatment chamber holding sludge being digested, passing sludge from the first treatment chamber to a second treatment chamber also holding sludge being digested, and withdrawing digested sludge from the second chamber, the two treatment chambers having a common wall across which heat is exchanged, and oxygenating the sludge in at least one of the chambers.

9. A method as claimed in claim 8, in which the sludge in the first chamber is held at a different temperature from the sludge in the second chamber.

10. A method as claimed in claim 9, in which the common wall is endless.

11. A method as claimed in any one of claims 8 to 10, in which there are at least three chambers and two endless common walls, one such wall defining a boundary between a first and a second chamber, and the other such wall defining a boundary between a second end of a third chamber.

12. A method as claimed in any one of claims 8 to 11, in which the walls of the chambers are generally tubular, the chambers being arranged concentrically.

13. A method as claimed in any one of claims 8 to 12, in which batches of sludge are passed from one chamber to the next at intervals in the range 18 to 36 hours.

14. A method as claimed in any one of claims 8 to 13, in which the first chamber encountered by incoming sludge for treatment contains sludge at a temperature in the range 35 to 40°C.

15. A method as claimed in claim 14, in which the sludge in the first chamber encountered by the incoming sludge is oxygenated.

16. A method as claimed in claim 14 or claim 15 in which the sludge in the other chamber or chambers is maintained at a temperature in the range 50 to 60°C.

17. A method as claimed in claim 16, in which the sludge in the other chamber or chambers is oxygenated.

18. A method as claimed in claim 16, in which the first and last chambers encountered by sludge is operated aerobically with oxygen being dissolved in the sludge held in such chambers, and the intermediate chamber or chambers, or at least one thereof, operated anaerobically.

19. A method as claimed in any one of claims 8 to 18, in which flow of a batch of sludge from one chamber to the next is through a penstock in common wall therebetween or over a weir.

20. A method for the thermophilic digestion of sludge, substantially as herein described with reference to Figs. 1 and 2, Fig. 3 or Fig. 4 of the accompanying drawings.

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